transient simulation. The model has a three-year warm-up period to recover from inaccuracies in the starting head field. PEST does not begin attempting to match modeled output with field observations until 1/1/1998. PEST adjusts recharge parameters as well as aquifer properties. The Modeling Technical Advisory Committee (MTAC) agreed to adjustment, within the bounds of uncertainty, on two of the components of recharge during model calibration. Adjustable components include irrigation-entity efficiency and tributary underflow. Irrigation entity efficiency describes what percentage of water diverted by an irrigation entity is consumptively used by crops. Tributary underflow is water entering the modeled aquifer system as groundwater from an adjacent aquifer.

Irrigation entity efficiency

An irrigation efficiency was assigned to all 89 irrigation entities. Conveyance losses were subtracted from the diverted volume before calculating entity efficiency for those entities with extensive canals (Figure 3). The lower and upper bounds for irrigation efficiency were set at 50% and 90%. Exceptions were made for entities the MTAC felt might benefit from natural sub-irrigation and for entities where water-measurement data indicated that entity efficiency could be outside the original bounds.

Tributary underflow

Prescribed-flux boundaries were used to represent tributary underflow for the major tributary valleys. Figure 4 shows the location of the 23 modeled tributary-underflow boundaries. Each tributary was assigned an initial long-term average underflow estimate as described in Appendix E of Fisher and others (2016). Tributary underflow was adjustable through three parameters: 1) a scalar that is multiplied with the initial long-term average estimate, 2) a moving average time span, and 3) an amplitude-reduction factor. Each tributary has a unique initial underflow estimate and a unique adjustable scalar. The moving average time span and amplitude-reduction factor are global and apply to all tributary valleys. Thus the flux at each tributary is unique, however the annual cycle (i.e., moving average and amplitude-reduction factor) are the same for all tributaries. This simplification is necessary because the data density in the tributary valleys is insufficient to allow adjustment of three unique tributary-underflow parameters for each of the 23 tributary valleys. The lower bound for each tributary scalar was set to 0.01 and the upper bound was set to a factor that would yield a product equal to 20% of the average annual precipitation within the tributary basin. The table in Figure 4 shows the average annual precipitation volume in each tributary basin and the modeled average annual underflow.

Aquifer hydraulic conductivity

The aquifer hydraulic conductivity distribution was estimated using a pilot-point parameterization method (Doherty, 2003). Parameter values were estimated for 271 pilot points and interpolated to the centroid of each model cell within the active model grid. Layer-one and Layer-three are divided into zones. The Layer-one zones separate the tributary valleys from the WRV (zone 1), and the Layer-three zones separate the alluvial aquifer (zone 1) from the basalt (zone 2). Layer-two consists of one zone. The delineation of the boundary between the lacustrine sediments, the sand and gravel, and the basalt portions of Layer-two is accomplished during calibration. Figures 5a through 5c show the various zones. The zones were defined based on geologic interpretation of driller logs.

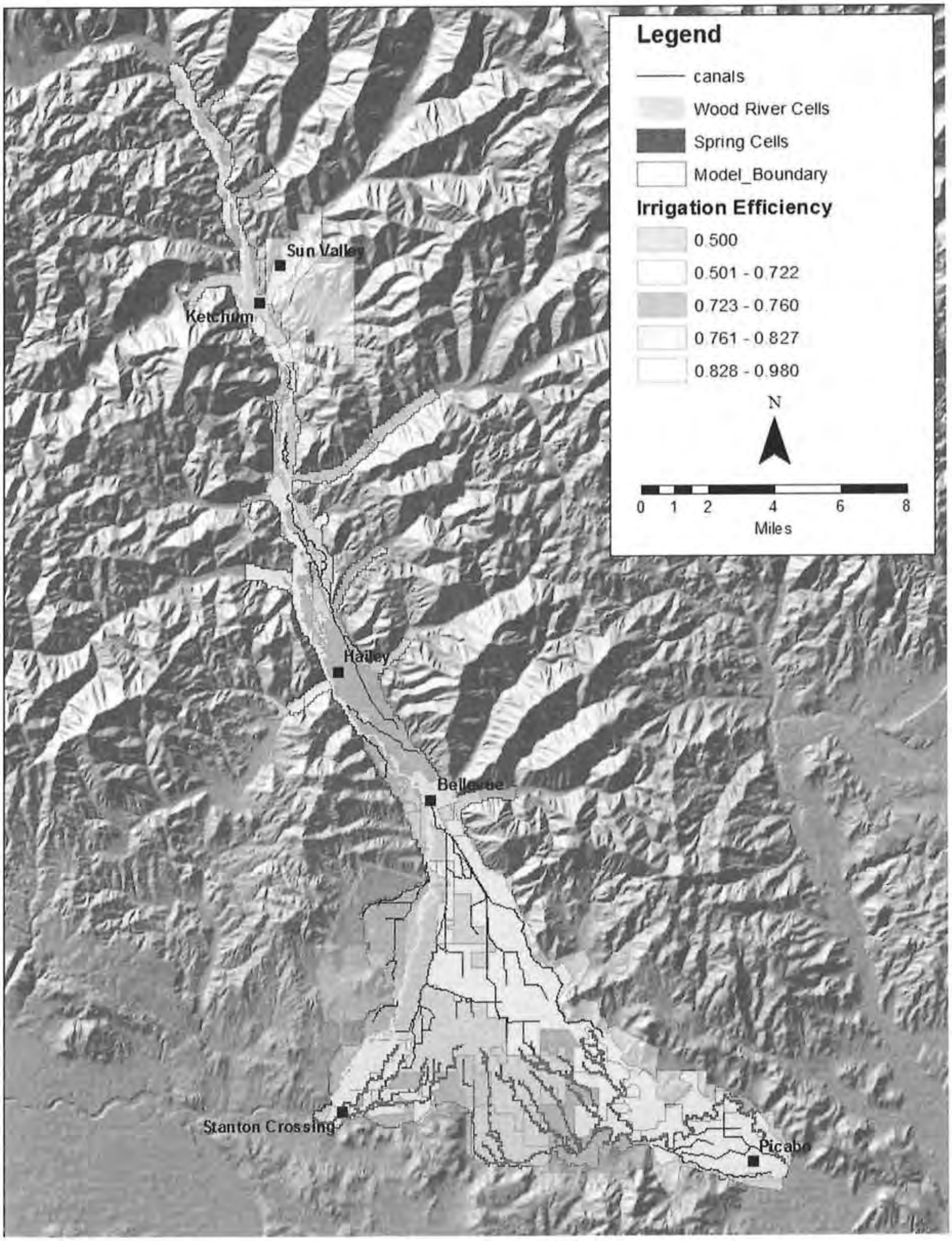
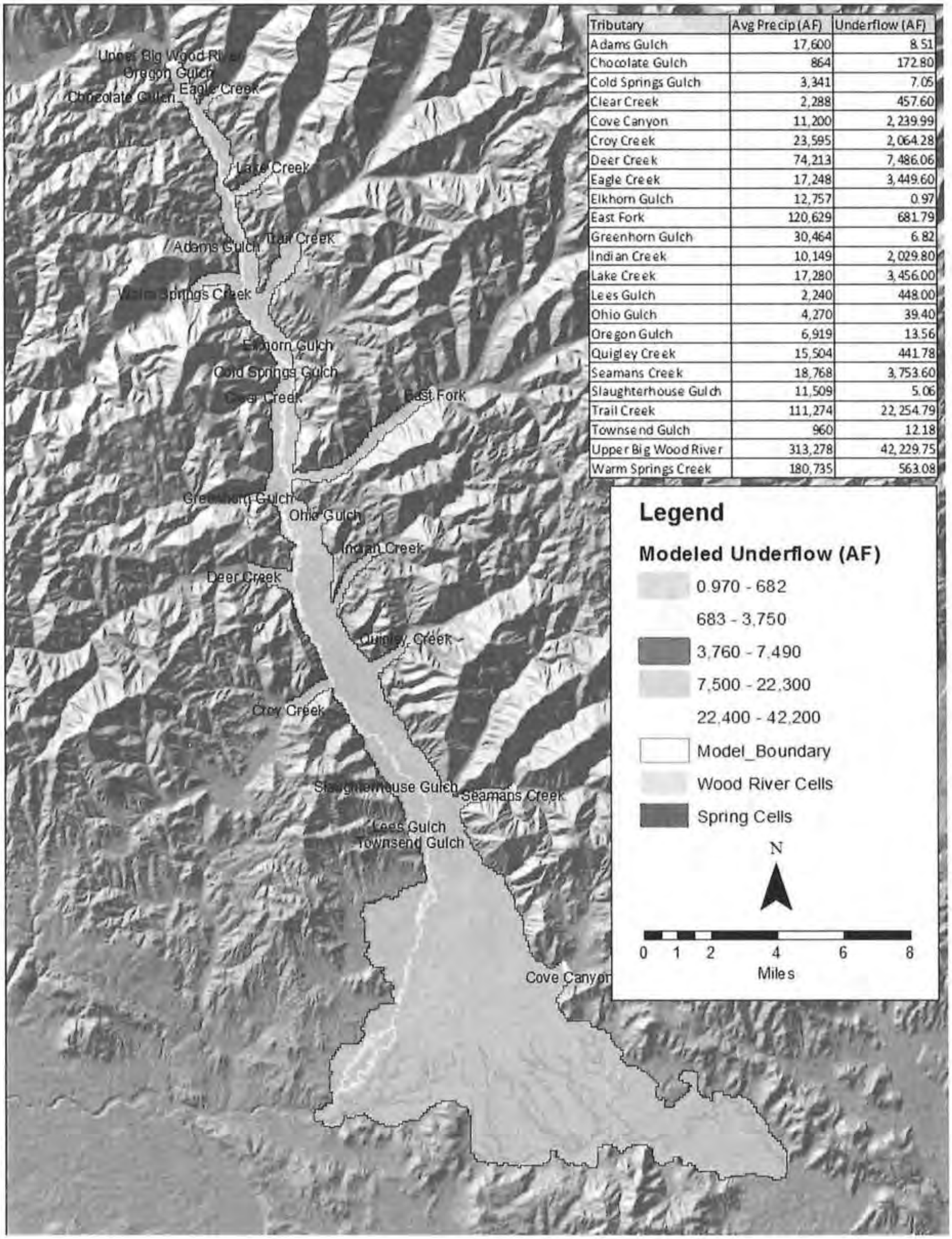


Figure 3. Irrigation entity efficiency.



Tributary	Avg Precip (AF)	Underflow (AF)
Adams Gulch	17,600	8.51
Chocolate Gulch	864	172.80
Cold Springs Gulch	3,341	7.05
Clear Creek	2,288	457.60
Cove Canyon	11,200	2,239.99
Croy Creek	23,595	2,064.28
Deer Creek	74,213	7,486.06
Eagle Creek	17,248	3,449.60
Elkhorn Gulch	12,757	0.97
East Fork	120,629	681.79
Greenhorn Gulch	30,464	6.82
Indian Creek	10,149	2,029.80
Lake Creek	17,280	3,456.00
Lees Gulch	2,240	448.00
Ohio Gulch	4,270	39.40
Oregon Gulch	6,919	13.56
Quigley Creek	15,504	441.78
Seamans Creek	18,768	3,753.60
Slaughterhouse Gulch	11,509	5.06
Trail Creek	111,274	22,254.79
Townsend Gulch	960	12.18
Upper Big Wood River	313,278	42,229.75
Warm Springs Creek	180,735	563.08

Figure 4. Tributary underflow.

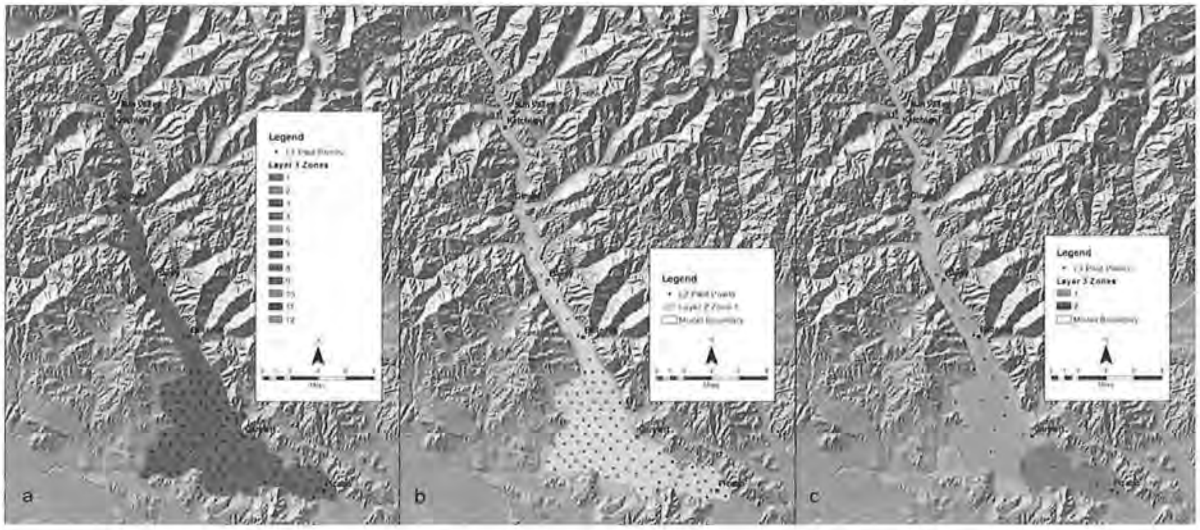


Figure 5. Hydraulic conductivity zones for Layers 1 (5a), 2 (5b), and 3 (5c).

Figures 6a through 6c show the calibrated hydraulic conductivity for Layer-one through Layer-three. Comparing Figure 3b from Fisher and others (2016) with Figure 6b in this document shows that for Layer-two, the calibration generally supports the delineation determined from the well logs. The major change is that calibration extends the lacustrine clays farther east toward Picabo. The resulting extent of the confining layer is consistent with earlier delineations of the confined aquifer (Moreland, 1977).

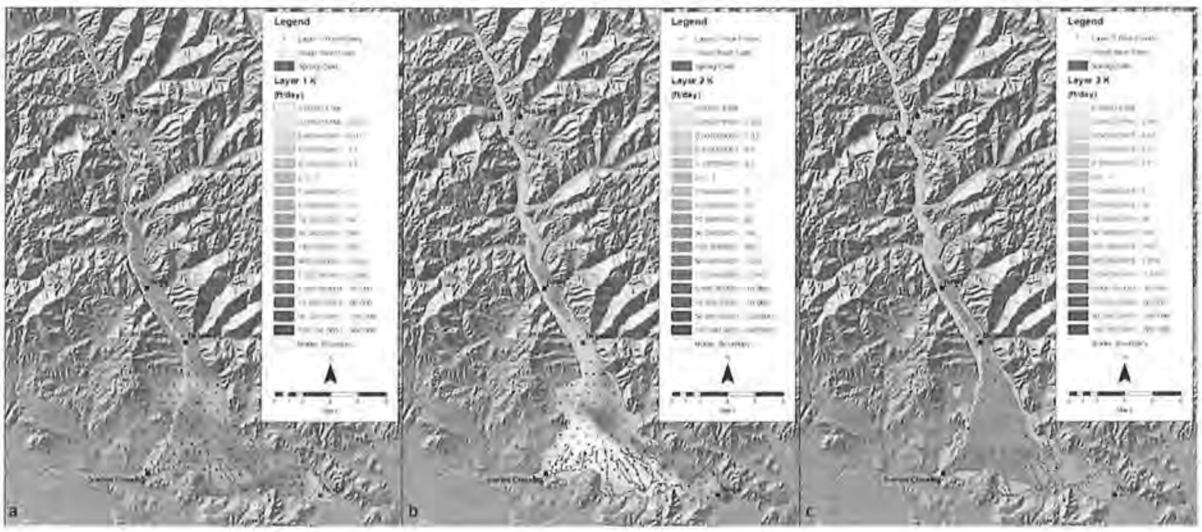


Figure 6. Calibrated hydraulic conductivity for Layers 1, 2, and 3.

Storage coefficient

The aquifer-storage coefficient distribution was calculated using a pilot-point parameterization method similar to the method used for the aquifer hydraulic conductivity distribution. The calibrated values are shown in Figures 7a through 7c.

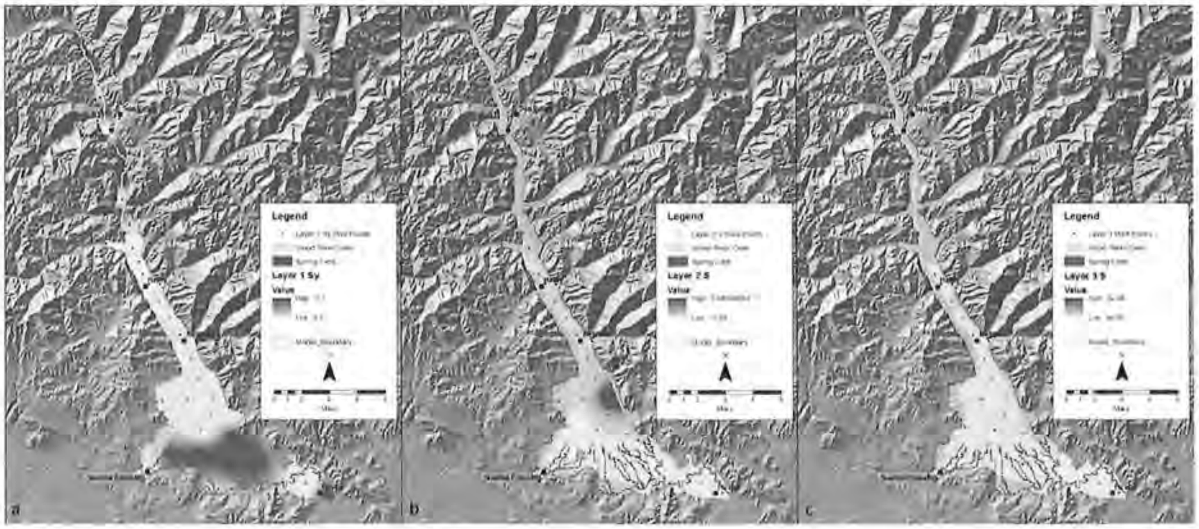


Figure 7. Calibrated aquifer storage coefficient for layers 1, 2, and 3, note that the color ramp is different for each layer.

All model layers were simulated using a fixed saturated thickness, so the storage coefficient for Layer-one is equivalent to a specific yield value. The calibrated storage coefficient values for Layer-one ranges from 0.10 to 0.30, consistent with literature estimates for alluvium (Freeze and Cherry, 1979). The calibrated values for Layers two and three range from 1.0e-6 to 9.7e-4.

Head-dependent river boundaries

Head-dependent boundaries are typically used to represent surface-water bodies which are hydraulically connected to an aquifer. Head-dependent boundaries include river boundaries, at which the flux may be either recharge or discharge from the aquifer, and drain boundaries, at which the flux may only be discharged from the aquifer (Panday and others, 2013). If the aquifer head in a river cell is above the water-surface elevation in the river (river stage), water flows from the aquifer into the river (aquifer discharge or river gain). If the aquifer head in a river cell is below the river stage, water enters the aquifer from the river (aquifer recharge or river loss).

For the purposes of this study, a river reach is a stretch of a river or stream defined by an upstream and downstream streamflow gage, or other means of determining flow. A subreach is a stretch of river or stream with an upstream and downstream measurement collected during one or more of the three seepage surveys conducted by the USGS during 2012 and 2013 (Bartolino, 2014). The Big Wood River, Silver Creek, and Willow Creek are represented by 2,551 river cells divided into five river reaches. The five river reaches (Figure 8a) are further subdivided into 21 subreaches (Figure 8b).

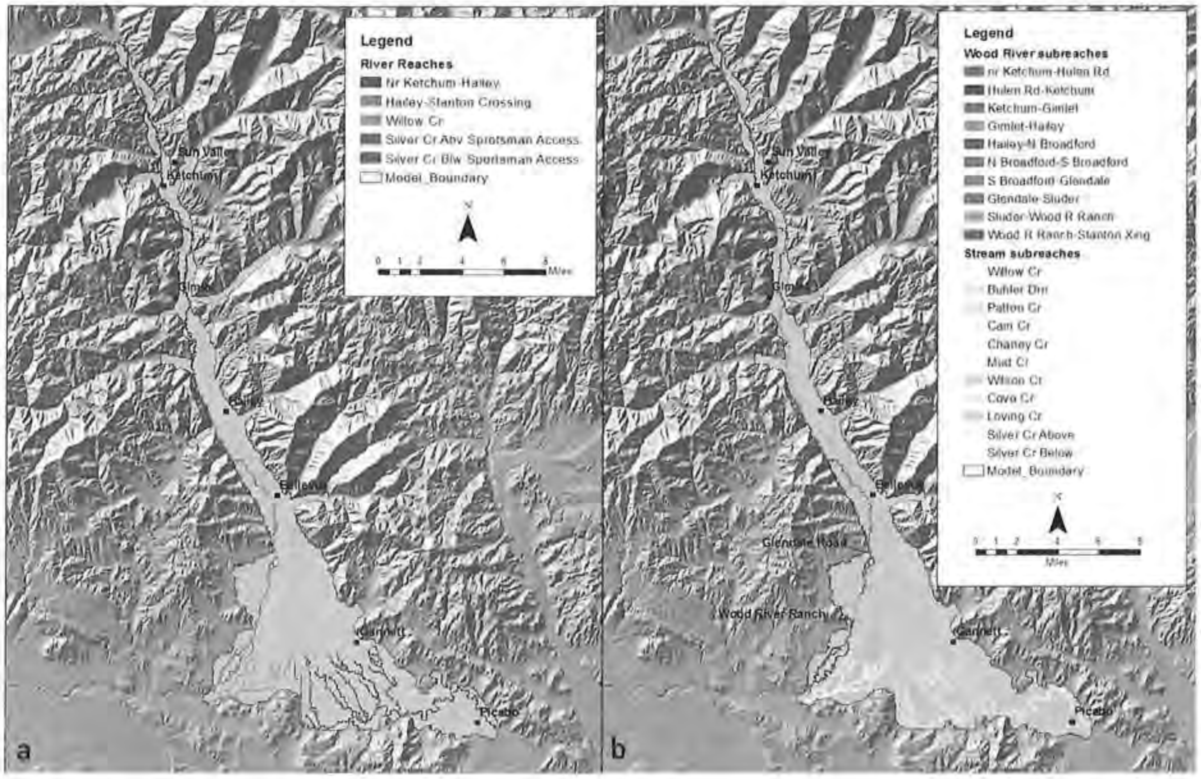


Figure 8. River reaches and subreaches.

River stage changes with each stress period along the Big Wood River. This is accomplished by interpolating between adjacent gages down to Glendale Road (Figure 8b). Landsat photos and water district records of priority cuts in surface-water rights are used to infer historical river conditions between Glendale Road and Stanton Crossing. When water district records indicate that the river was dry between Glendale Road and Wood River Ranch, river stage was set equal to the river bottom so the river head differential is zero and no water can leak from the river. When Landsat photos indicate water was flowing between Glendale Road and Wood River Ranch, river stage was set above the river bottom so water can seep from the river. When Landsat photos indicate that water is flowing between Wood River Ranch and Stanton Crossing, river stage is interpolated between Stanton Crossing and Wood River Ranch. When Landsat photos indicate that the river is dry, river stage is set equal to the river bottom.

The riverbed-conductance parameters are adjustable parameters that help govern seepage into and out of the river. Riverbed conductance is constant through time for most subreaches. The seepage from the river to the aquifer or from the aquifer to the river is a function of river stage, aquifer head, and riverbed conductance.

Generally, flow in a river is a function of stage in the river; the higher the stage, the higher the flow (Sanders, 1998). However, in the Glendale Road to Sluder Road and Sluder Road to Wood River Ranch subreaches, the river stage does not increase significantly as flow increases rather, the river spreads laterally. To approximate this phenomenon, different riverbed conductance parameters were provided when the average monthly river stage at Hailey exceeded certain values. When the average monthly river stage at Hailey was less than three feet, a riverbed-conductance term representing normal flow conditions was used; when the average monthly river stage exceeded three feet, a riverbed-conductance term representing high-flow conditions was used; and when the average monthly river stage exceeded 4.5 feet, a riverbed-conductance term representing especially high-flow conditions was used. Thus, there are three riverbed-conductance parameters used for the Glendale Road to Sluder Road subreach and three riverbed-conductance parameters use for the Sluder Road to Wood River Ranch subreach and the parameter that is used depends on the river stage recorded at the Hailey gage. Figure 1 shows the location of the gages, Figure 8b shows the location of the subreaches, and Figure 9 shows the recorded average monthly stage at the Hailey gage.

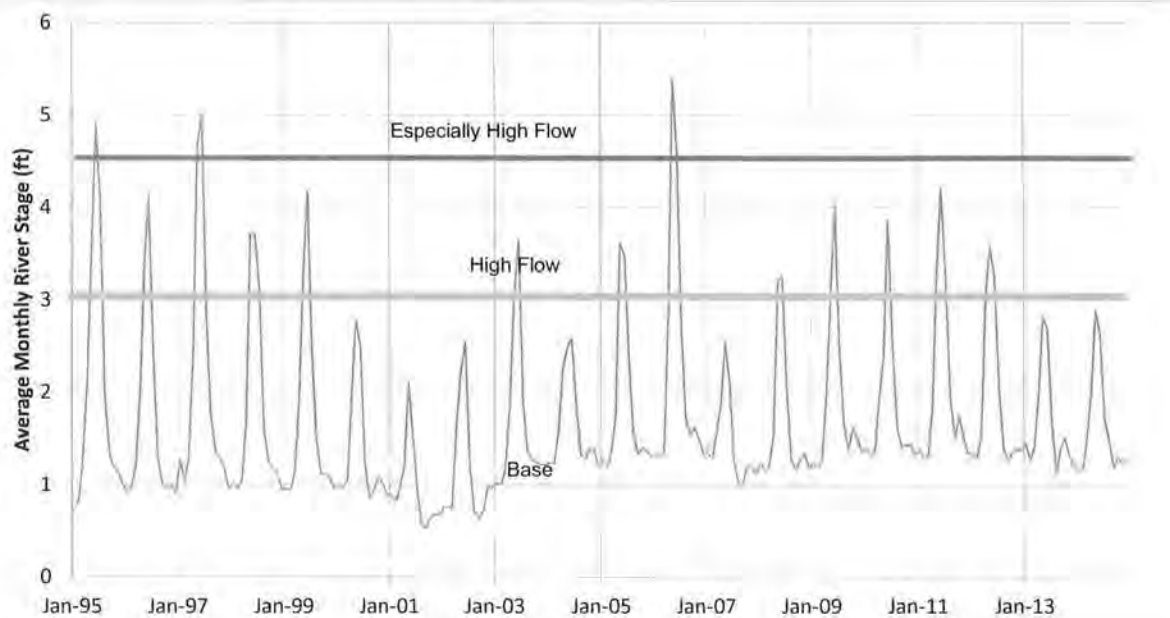


Figure 9. Average monthly stage recorded at Hailey.

Figure 10a shows the range of calibrated riverbed-conductance values for the Big Wood River with the base riverbed conductance for the Glendale Road to Sluder Road and Sluder Road to Wood River Ranch subreaches. Figures 10b and 10c show the riverbed conductance for higher flow conditions.

Figure 11 shows the range of calibrated riverbed-conductance values used to simulate aquifer and river interactions for Silver Creek and Willow Creek.

Figure 12a through 12d show the observed river gains and losses. Note that the gains depicted in Figure 12a frequently contain gaps during the spring. This is because of gage error at high flow and because there are several ungaged ephemeral tributary streams that likely contributed flow to the Big Wood River during this time; thus, not all the ungaged gains were contributions from the WRV aquifer system. The lack of tributary-stream measurements in these ephemeral streams and the possibility of gage error at high flows precludes calculation of reach gains and losses during these periods.